APPENDIX A

Final
Geophysical Survey Report
Range I, Parcel 201(7)

Fort McClellan, Calhoun County, Alabama

February 2001

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List of Acronyms

See Attachment 1, List of Abbreviations and Acronyms, of the site-specific field sampling plan attachment contained in this binder.

A.1.0 Introduction

IT Corporation (IT) conducted a surface geophysical survey at Range I, Parcel 201(7), at Pelham Range, Fort McClellan, Calhoun County, Alabama, on October 31, 2000. This survey was conducted for the U.S. Army Corps of Engineers (USACE)-Mobile District, under Total Environmental Restoration Contract Number DACA21-96-D-0018, Task Order CK05. The geophysical activities were designed to fulfill requirements of the memorandum of agreement between the National Guard and the U.S. Army with regard to the transfer of Pelham Range to the Alabama National Guard. The geophysical survey objectives were to screen the area for the presence of buried drums or munitions suggested in historical reports. The total area surveyed was approximately 40,000 square feet (0.92 acre). The vicinity map (Figure A-1) shows the approximate location of the survey area.

To accomplish the objectives of the investigation, magnetic and frequency-domain electromagnetic (EM) induction methods were used. All geophysical data were processed and color-enhanced to aid in interpreting subtle anomalies. Following geophysics fieldwork, a submeter global positioning system (GPS) was used to document the site location.

The survey area has a flat topography with a gentle slope towards the east. There are some mounds and depressions scattered throughout the area as shown on the site map with geophysical interpretation (Figure A-2). The site is primarily tree covered with small areas of brush.

Field procedures used during the investigation are described in Chapter A.2.0. The data processing methods used during the investigation are presented in Chapter A.3.0. Data interpretation and criteria used to interpret geophysical anomalies are presented in Chapter A.4.0. Conclusions and recommendations derived from the geophysical surveys are presented in Chapter A.5.0. A description of the equipment and a theoretical discussion of the geophysical methods are presented in the attachment to this appendix.

A.2.0 Field Procedures

Field procedures presented in this chapter include discussions of the survey control and site map, field equipment, data acquisition parameters, and field verification of geophysical anomalies.

A.2.1 Survey Control

The geophysical survey area was identified in the site-specific work plan based on historical site information compiled by IT and Assessment Number 38-EH-1775-99 by the U.S. Army Center for Health Promotion and Preventive Maintenance. The geophysics crew established a base grid on 100-foot centers throughout the site. Using the base grid as a reference, a line spacing of 10 feet with control points marked on 10-foot centers with surveyor's paint was used to provide the spatial control required for the investigation. Due to the uncertainty of true field positions inherent when establishing a survey area using 300-foot fiberglass tapes in the presence of wind and surface obstructions (e.g., trees and rough terrain), the lateral precision for the survey areas and anomalies is estimated to be within ±1 foot. Following geophysics field work, a GPS survey was conducted at the site referencing the U.S. State Plane Coordinate System (Alabama East Zone, North American Datum of 1983). The GPS survey provided submeter resolution in XY coordinates for the site.

A detailed site map was hand drawn in the field. The map included any surface cultural features within the survey area or near the perimeter that could potentially affect the geophysical data (e.g., topographic slopes, mounds, and wire fences). The map also shows reference features, such as fences, depressions, and mounds that could later aid in reconstructing the site boundaries. All pertinent reference information documented on the hand drawn site map was placed on the site interpretation map (Figure A-2). GPS coordinates are included on the site map to help relocate the survey area.

A.2.2 Geophysical Survey

Field Instruments. The magnetic instruments used during the investigation consisted of a Geometrics, Inc. G-858G magnetic gradiometer (G-858G) for collecting survey data and a Geometrics, Inc. G-856AX for collecting magnetic base station data. Frequency-domain EM induction equipment consisted of a Geonics EM31 Terrain Conductivity Meter (EM31) coupled to an Omnidata DL720 digital data logger.

All geophysical data were collected using the following IT standard operating procedures:

- ITGP-001 Surface Magnetic Surveys
- ITGP-002 Surface Frequency-Domain Electromagnetic Surveys
- ITGP-005 Global Positioning System Survey
- ITGP-012 Geophysical Data Management.

Field Instrument Base Station. A field instrument base station was established at the Range I site to provide quality control for the collected geophysical survey data. The base station location was determined to be free of surface and subsurface cultural features that could affect the geophysical data. Standard field procedures were used to occupy the base station and collect readings with the survey instruments (magnetic and EM31) before and after each data collection session. These base station files were then reviewed to assess instrument operation. Base station file names and average data values within them were recorded on base station summary forms.

A.2.2.1 Magnetic Survey

Magnetic Base Station. A magnetic base station was established at Fort McClellan to record the background fluctuation (diurnal drift) of the Earth's magnetic field. The magnetic base station was located in a field of small pine trees on the south side of Sixth Avenue (near Parcel 151), a location which was determined to be free of surface and subsurface cultural features that could affect the data. A G-856AX magnetometer was used for the magnetic base station. Adequate background magnetic field data was collected and used to "drift correct" the survey data. The background magnetic field data collected at the base station was reviewed, and it was determined that the survey was conducted during a time of magnetic quiescence.

G-858G Data Collection. Magnetic field measurements were made with the two sensors of the G-858G spaced 2.5 feet (0.76 meter) apart; the lower sensor was 2.0 feet above the ground surface, and the upper sensor was 4.5 feet above the ground surface. At the start and end of each data collection session, approximately 60 readings were recorded with the G-858G at the field instrument base station to verify that the instrument was operating properly, and to provide a quantitative record of instrument variation during the survey period. A review of these base station files indicates that the instrument was operating properly and the instrument drift was within acceptable limits. Magnetic survey data were collected at 0.5-second intervals (approximately 2.0 to 2.5-foot intervals) along east to west (E-W) oriented survey lines (in order to cross perpendicular to "mounded" areas of concern as preferred by the IT Principal Investigator) spaced 10 feet apart, for a total of approximately 4,200 linear feet of survey coverage.

The magnetic data were stored in the internal memory of the G-858G, along with corresponding line and station numbers and time of acquisition. Magnetic survey data were screened in the field to assess data quality prior to completing the investigation. All magnetic survey and base station data were downloaded to a personal computer, backed up on IOMEGA® compatible zip disks, and are retained in project files.

A.2.2.2 Frequency-Domain EM Survey

EM31 Data Collection. Prior to conducting the EM31 survey, the instrument was calibrated, and the in-phase component zeroed at the field instrument base station. The instrument was operated in the vertical dipole mode, measuring the in-phase and out-of-phase components of the secondary EM field. At the start and end of each data collection session, approximately 20 readings were recorded at the field instrument base station to verify that the instrument was operating properly and to provide a quantitative record of instrument variation, or drift, during the survey period. A review of these base station files indicates that the instrument was operating properly and instrument drift was within acceptable limits. Survey data were collected at 5-foot intervals along E-W oriented survey lines spaced 10 feet apart, for a total of approximately 4,200 linear feet of survey coverage.

The EM31 data were stored in the digital data logger along with corresponding line and station numbers. EM31 line profiles were reviewed in the field using the DAT31® program to verify data quality prior to completing the survey. All EM31 survey and base station data were downloaded to a personal computer, backed up on IOMEGA® compatible zip disks, and are retained in project files.

A.2.2.3 Anomaly Verification

Anomaly Verification. Preliminary color-contour maps of the magnetic and EM31 data were generated and field-checked to differentiate between anomalies caused by surface and subsurface sources. Geophysical anomalies verified as being caused by surface features were labeled as such on the field data map. Anomalies caused by buried metallic objects were carefully located in the field and marked on the site map.

A.3.0 Data Processing

Color Contour Maps. Plots of magnetic and EM31 data were generated using the OASIS Montaj® geophysical mapping system from Geosoft, Inc. These maps were color-enhanced to aid with interpreting subtle anomalies. Select contour maps from this site are presented as Figures A-3 through A-5.

A series of data processing steps were required to generate the contour maps. Magnetic gradiometer data were downloaded from the field instrument and converted to an ASCII file using Geometrics, Inc. MAGMAP2000® program. EM31 data were downloaded from the data logger and converted to ASCII files using DAT31® software from Geonics, Inc. The ASCII data files were then reviewed to assess line numbers, station ranges, and overall data quality. Field data file names and corresponding base station data files were recorded on the data file tracking form. Data screening results were then recorded on the base station summary form. Following data quality assessment, geometry corrections to field data files were made, if necessary, using a text editor, and recorded on the geophysical data editing form.

Final, corrected magnetic and EM data files containing local geophysical station coordinates (X,Y) and the geophysical measurement (Z) were converted to OASIS Montaj® format and imported into the geophysical mapping software. The data were then gridded using bidirectional gridding with an Akima spline. The grid cell size for the magnetic and EM31 data was chosen to be 0.5 and 2.5 feet, respectively. Color contouring was used to enhance data anomalies. The names of files generated and processing parameters used were recorded on data processing forms. Final processed map names are shown in the data processing box found in the lower left corner of each contour map presented. All completed forms of magnetic and EM data collected during the investigation are retained in project files.

A.4.0 Interpretation of Geophysical Data

The method by which the geophysical data were interpreted and the results of that interpretation are presented in this chapter.

Figure A-2 presents the site map with geophysical interpretation. The interpreted color-contour map of total magnetic field for the upper sensor is presented as Figure A-3. Interpreted color-contour maps of EM31 in-phase component and conductivity data collected along E-W survey lines are presented as Figures A-4 and A-5, respectively. A theoretical background is presented as an attachment to this appendix. The attachment discusses the factors influencing the observed geophysical response for the various methods and equipment used to conduct the survey at Range I.

In addition to the geophysical interpretation, the site map (Figure A-2) contains detailed information on reference features (e.g., topographic slopes and fences), so that the survey area and the geophysical anomaly locations can be relocated in the future. Anomalies shown on the site interpretation map correspond to those seen in the magnetic and EM data. Surface reference features shown on the site interpretation map were translated from the hand-drawn site map made in the field. The site interpretation map also references the Alabama East State Plane, North American Datum of 1983 Coordinate System.

A.4.1 Data Interpretation Criteria

Color Contour Map Anomalies. Anomalies shown on the magnetic and EM contour maps range from high to low and from negative to positive values, depending on the type of data displayed. The observed anomalies in the contour map of total magnetic field for the upper sensor have values above and below the average magnetic field intensity of 51,300 nanoTeslas for Anniston, Alabama. The typical magnetic data response to near-surface ferrous metallic debris is an asymmetric south high/north low signature. The upper sensor magnetic data are more useful than the lower sensor data for locating large buried objects because the lower sensor is more sensitive to small near-surface objects; hence the upper sensor magnetic data are presented. The characteristic EM31 anomaly over a near-surface metallic conductor consists of a narrow zone having strong negative amplitude centered over the target and a broader lobe of weaker, positive amplitude on either side of the target. As the depth of the target feature increases, the characteristic EM31 response changes to a positive amplitude centered over the target.

Anomalies present on the contour maps of magnetic and EM31 data were field-checked and correlated with known metallic surface objects and other cultural surface features so that anomalies caused by subsurface sources could be determined. Many of the high-amplitude anomalies seen in the contour maps of the magnetic and EM31 data (Figures A-3 through A-5) are caused by cultural features that include metallic debris and wire fence. Anomalies caused by surface metal are labeled as such on the data contour maps, and the locations of these features are indicated on the geophysical interpretation map.

A.4.2 Range I Data Interpretation

All of the high-amplitude anomalies seen in the contour maps of the magnetic and EM31 data (Figures A-3 through A-5) are caused by surface metal objects and/or partially buried objects. The geophysical interpretations map (Figure A-2) shows the locations of surface metal that was observed in the data.

A.5.0 Conclusions and Recommendations

A surface geophysical survey using magnetic and EM methods were conducted on October 31, 2000 at Range I, Parcel 201(7), at Pelham Range. The survey objectives were to screen the area for the presence of buried drums or munitions suggested in historical reports.

Geophysical data analysis indicates no evidence of areas containing buried metal drums or munitions. The anomaly seen in the magnetic data is caused by the remnants of a wire fence that enclosed the area. The EM31 in-phase data show several anomalies that are caused by individual surface metal objects. The EM31 conductivity data show a northeastward increase in conductivity of no significance. The interpretation map shows the locations of all the cultural features and individual surface metal objects.

After the geophysical data interpretation was complete, all of the anomalies were interpreted to represent surface metal objects. These objects are shown on Figure A-2.

A hand-drawn field map and GPS survey of site features provided a permanent record of the survey boundaries and anomaly locations. Positions on the site map generated (Figure A-2) are conservatively estimated to be accurate to within ±1 foot.

Based on the objectives and results of the geophysical survey presented in this report, no further geophysical effort is recommended at the Range I site.

ATTACHMENT

THEORETICAL BACKGROUND

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See Attachment 1, List of Abbreviations and Acronyms, of the site-specific field sampling plan attachment contained in this binder.

1.0 Magnetic Method

The magnetic instruments used during the Fort McClellan surface geophysical surveys were a Geometrics, Inc., G-858G "walking mode" magnetic gradiometer (G-858G) for acquiring survey data, and a Geometrics, Inc., G-856 for collecting magnetic base station data.

The G-858G, which is an optically-pumped cesium vapor instrument, measures the intensity of the Earth's magnetic field in nanoTeslas (nT) and the vertical gradient of the magnetic field in nanoTeslas per meter (nT/m). The vertical gradient is measured by simultaneously recording the magnetic field with two sensors at different heights. To determine the vertical magnetic gradient, the upper sensor reading is subtracted from the lower sensor reading, and the result is then divided by the distance between the sensors. The distance between sensors for this investigation was 2.5 feet (0.76 meter). The vertical magnetic gradient measurement allows for better definition of shallower anomalies.

During operation of the G-858G magnetic gradiometer, a direct current is used to generate a polarized monochromatic light. Absorption of the light occurs within the naturally precessing cesium atoms found in the instrument's two vapor cells or sensors. When absorption is complete, the precessing atoms become a transfer mechanism between light and a transverse radio-frequency field at a specific frequency of light known as the Larmor frequency. The light intensity is used to monitor the precession and adjusts the radio frequency allowing for the determination of the magnetic field intensity (Sheriff, 1991).

The Earth's magnetic field is believed to originate in currents in the Earth's liquid outer core. The magnetic field varies in intensity from approximately 25,000 nT near the equator, where it is parallel to the Earth's surface, to approximately 70,000 nT near the poles, where it is perpendicular to the Earth's surface. In Alabama, the intensity of the Earth's magnetic field varies from 51,000 nT to 52,000 nT, and has an associated inclination of approximately 54 degrees.

Anomalies in the Earth's magnetic field are caused by induced or remnant magnetism. Remnant magnetism is caused by naturally occurring magnetic materials. Induced magnetic anomalies result from the induction of a secondary magnetic field in a ferromagnetic material (e.g., pipelines, drums, tanks, or well casings) by the Earth's magnetic field. The shape and amplitude of an induced magnetic anomaly over a ferromagnetic object depends on the geometry, size, depth, and magnetic susceptibility of the object, and on the magnitude and inclination of the Earth's magnetic field in the study area (Dobrin, 1976; Telford, et al., 1976). Induced magnetic anomalies over buried objects such as drums, pipes, tanks, and buried metallic debris generally exhibit an asymmetrical, south high/north low signature (maximum amplitude on the south side and minimum on the north in the Northern Hemisphere). Magnetic anomalies caused by buried metallic objects generally have dimensions much greater than the dimensions of the objects themselves. As an extreme example, a magnetometer may begin to sense a buried oil well casing at a distance of greater than 50 feet.

The magnetic method is not effective in areas with ferromagnetic material at the surface because the signal from the surface material obscures the signal from any buried objects. Also, the presence of an alternating current electrical power source can render the signal immeasurable because of the high precision required in the measurement of the frequency at which the protons precess (Breiner, 1973). The precession signal may also be sharply degraded in the presence of large magnetic gradients (exceeding approximately 600 nT/m).

The magnetic field measured at any point on the Earth's surface undergoes low-frequency diurnal variation, called magnetic drift, associated with the Earth's rotation. The source of magnetic drift is mainly within the ionosphere, and its magnitude is sometimes large enough to introduce artificial trends in survey data. The G-856 base station magnetometer was used to record this drift for removal from the G-858G survey data during processing.

Applications of the magnetic method include delineating old waste sites and mapping unexploded ordnance (UXO), drums, tanks, pipes, abandoned wells, and buried metallic debris. The method also is useful in searching for magnetic ore bodies, delineating basement rock, and mapping subsurface geology characterized by volcanic or mafic rocks.

2.0 Frequency-Domain EM Method

Frequency-domain electromagnetic (EM) induction equipment used during this investigation consisted of a Geonics EM31 terrain conductivity meter (EM31) coupled to an Omnidata DL720 digital data logger. The EM31 consists of a 12-foot-long plastic boom with a transmitter coil mounted at one end and a receiver coil at the other. An alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. As described by Faraday's law of induction, this time-varying magnetic field generates eddy currents in conductive subsurface materials. These eddy currents have an associated secondary magnetic field with a strength and phase shift (relative to the primary field) that are dependent on the conductivity of the medium. The combined effect of the primary and secondary fields is measured by the receiver coil in-phase (in-phase) and 90 degrees out-of-phase (quadrature) with the primary field. Most geologic materials are poor conductors. Current flow through geologic materials takes place primarily in the pore fluids (Keller and Frischknecht, 1966); as such, conductivity is predominantly a function of soil type, porosity, permeability, pore fluid ion content, and degree of saturation. The EM31 is calibrated so that the out-of-phase component is converted to electrical conductivity in units of millisiemens per meter (McNeill, 1980), and the in-phase component is converted to parts per thousand of the secondary field to the primary EM field. The in-phase component is a relative value that is generally set to zero over background materials at each site.

The depth of penetration for EM induction instruments depends on the transmitter/receiver separation and coil orientation (McNeill, 1980). The EM31 has an effective exploration depth of approximately 18 feet when operating in the vertical dipole mode (horizontal coils). In this mode, the maximum instrument response results from materials at a depth of approximately two-fifths the coil spacing (or, approximately 2 feet below ground surface with the instrument at the normal operating height of approximately 3 feet), providing that no large metallic features such as tanks, drums, pipes, and reinforced concrete are present. Single buried drums typically can be located to depths of approximately 5 feet, whereas clusters of drums can be located to significantly greater depths if background noise is limited or negligible. In the horizontal dipole mode (vertical coils), the EM31 has an effective exploration depth of approximately 9 feet and is most sensitive to materials immediately beneath the ground surface.

The EM31 generally must pass over or very near a buried metallic object to detect it. Both the out-of-phase and in-phase components exhibit a characteristic anomaly over near-surface metallic conductors. This anomaly consists of a narrow zone having strong negative amplitude centered over the target and a broader lobe of weaker, positive amplitude on either side of the target. For long, linear conductors such as pipelines, the characteristic anomaly is as described when the axis of the coil (instrument boom) is at an angle to the conductor. However, when the instrument boom is oriented parallel to the conductor, a positive amplitude anomaly is obtained.

The application of frequency-domain EM techniques includes mapping conductive groundwater contaminant plumes in very shallow aquifers, delineating oil brine pits, landfill boundaries and pits and trenches containing buried metallic and nonmetallic debris, and locating buried pipes, cables, drums, and tanks.

3.0 References

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